

Docket No. 224569US25SD

IN RE APPLICATION OF: Chen

SERIAL NO: 09/833,016

FILED: April 10, 2001

FOR: FORCE-BALANCE ROLLER CONE BITS, SYSTEMS, DRILLING METHODS, AND DESIGN METHODS

COMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313

SIR:

Transmitted herewith is an amendment in the above-identified application.

- ☒ No additional fee is required
- ☐ Small entity status of this application under 37 C.F.R. §1.9 and §1.27 is claimed.
- ☒ Additional documents filed herewith: 37 CFR 1.604 Request for an Interference with an Application

The Fee has been calculated as shown below:

CLAIMS	CLAIMS REMAINING		HIGHEST NUMBER PREVIOUSLY PAID	NO. EXTRA CLAIMS	RATE	CALCULATIONS
TOTAL	17	MINUS	33	0	x \$18 =	\$0.00
INDEPENDENT	9	MINUS	9	0	x \$84 =	\$0.00
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIMS					+ \$280 =	\$0.00
TOTAL OF ABOVE CALCULATIONS						\$0.00
<input type="checkbox"/> Reduction by 50% for filing by Small Entity						\$0.00
<input type="checkbox"/> Recordation of Assignment					+ \$40 =	\$0.00
TOTAL						\$0.00

- ☐ A check in the amount of \$0.00 is attached.
- ☐ Credit card payment form is attached to cover the fees in the amount of \$0.00
- ☒ Please charge any additional Fees for the papers being filed herewith and for which no check or credit card payment form is enclosed herewith, or credit any overpayment to deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.
- ☒ If these papers are not considered timely filed by the Patent and Trademark Office, then a petition is hereby made under 37 C.F.R. §1.136, and any additional fees required under 37 C.F.R. §1.136 for any necessary extension of time may be charged to Deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

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TO		Examiner R. W. Frejd	August 25, 2003
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MESSAGE

Per the telephone message I left on Friday, August 22nd, attached is the 37 CFR 1.604(a)(1) Amendment and 37 CFR 1.604 Request that we filed on Friday.

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Appl. No. 09/833,016

Filed with 37 CFR 1.604(a)(1) Request

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*Incomplete copy
of Paper #17*

DOCKET NO: 224569US25SD

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF

CHEN

: EXAMINER: R. W. FREJD
(ANTICIPATED)

SERIAL NO: 09/833,016

FILED: APRIL 10, 2001

: GROUP ART UNIT: 2123

FOR: FORCE-BALANCED ROLLER-
CONE BITS, SYSTEMS, DRILLING
METHODS, AND DESIGN METHODS37 CFR 1.604 REQUEST FOR AN
INTERFERENCE WITH AN APPLICATIONCOMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313
SIR:I. 37 CFR 1.604(a)(1)

Applicant proposes the following count, which is in the format approved by the Commissioner in Orikasa v. Oonishi, 10 USPQ2d 1996, 2003 (Comm'r 1990), and Davis v. Uke, 27 USPQ2d 1180, 1188 (Comm'r 1993):

Claims 1, 5, 10, 16, 22, 23, 24, 25, and 26 of the party Huang's application serial No. 09/635,116

OR

Claims 34, 35, 36, 40, 46, 47, 48, 49, and 50 of the party Chen's application serial No. 09/833,016.

Claims 34-50 presented in the 37 CFR 1.604(a)(1) amendment submitted herewith correspond to the proposed count. Indeed, the proposed count includes all of the independent claims in that group of claims.

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II. 37 CFR 1.604(a)(2)

The other application is application serial No. 09/635,116 filed August 09, 2000 and naming Huang et al. as inventors. If that application is now abandoned, this request is directed to any continuation of that application now pending.

Applicant believes that all claims in application serial No. 09/635,116 or any continuation of that application now pending correspond to the proposed count. Since applicant does not have access to that application, he cannot be sure. This request is based on the fact that the assignee of the Huang application has informed the assignee of the Chen application that the subject matter of Huang's claims 1-27 has been allowed in Huang's application. Applicant does not know the actual claim numbers used in the Huang application. The copy of Huang's claims provided to Chen's assignee by Huang's assignee were numbered 1-27.

III. 37 CFR 1.604(a)(3)

The interference should be declared because, as shown by the table below, the parties are claiming the same patentable invention.

Chen's Application

34. A method for determining a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

selecting at least one characteristic of an earth formation to be simulated as being drilled by the drill bit;

simulating drilling of the earth

Huang's Application

5. A method for determining a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selection bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

selecting at least one characteristic of an earth formation to be simulated as being drilled by the drilling bit;

simulating drilling of the earth

formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations; and

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones.

35. A method for balancing a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

selecting at least one characteristic of an earth formation to be simulated as being drilled by the drill bit;

simulating drilling of the drill bit through the earth formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of simulated incremental rotations;

combining the volume of each crater

formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater,

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations; and

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones.

16. A method for balancing a volume of formation cut by each of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

selecting at least one characteristic of an earth formation to be simulated as being drilled by the drill bit;

simulating drilling of the drill bit through the earth formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater,

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of simulated incremental rotations;

combining the volume of each crater

formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones; and

adjusting at least one of the bit design parameters, and repeating the calculating the crater volume, incrementally rotating and combining the volume simulating until a difference between the combined volume cut by each of the cones is less than the combined volume determined prior to the adjusting the at least one of the bit design parameters.

formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones; and

adjusting at least one of the bit design parameters, and repeating the simulating until a difference between the combined volume cut by each of the cones is less than the combined volume determined prior to the adjusting the at least one of the bit design parameters.

17. The method as defined in claim 16 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

18. The method as defined in claim 17 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

19. The method as defined in claim 18 wherein an incremental axial movement of the drill bit corresponding to the incrementally rotating is adjusted to cause the axial force on each of the cutting elements to total the axial force applied to the drill bit, the axial force acting on each of the cutting elements determined with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.

36. A method for determining an axial force acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

simulating drilling of an earth formation by the roller cone bit, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;

repeating the simulating the incrementally rotating and recalculating for a selected number of incremental rotations; and

combining the axial force acting on the cutting elements on each one of the roller cones to determine the axial force acting on each of the roller cones.

37. The method as defined in claim 16 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

1. A method for determining an axial force acting on each one of a plurality of roller cones on a roller cone drill bit during drilling comprising:

simulating drilling of an earth formation by the roller cone bit, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;

repeating the simulating the incrementally rotating and recalculating for a selected number of incremental rotations; and

combining the axial force acting on the cutting elements on each one of the roller cones to determine the axial force acting on each of the roller cones.

2. The method as defined in claim 1 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

3. The method as defined in claim 2 wherein an incremental axial movement of the drill bit corresponding to the incrementally rotating is adjusted to cause the axial force on each of the cutting elements to total the axial force applied to the drill bit, the axial force acting on each of the cutting elements determined with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.

4. The method as defined in claim 3 wherein the predetermined relationship is determined by laboratory experiment comprising impressing a cutting element

38. The method as defined in claim 17 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

39. The method as defined in claim 18 further wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

having known geometry onto a selected earth formation, while measuring force on the cutting element and a corresponding depth of penetration of the cutting element into the selected earth formation.

6. The method as defined in claim 5 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

calculating, from an axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

7. The method as defined in claim 6 further wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

8. The method as defined in claim 7 wherein an incremental axial movement on the drill bit corresponding to the incrementally rotating is adjusted to cause the axial force on each of the cutting elements to total the axial force applied to the drill bit, the axial force acting on each of the cutting elements determined with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting geometry and the earth formation.

9. The method as defined in claim 8 wherein the predetermined relationship is determined by laboratory experiment comprising impressing a cutting element having known geometry onto a selected earth formation, while measuring force on the cutting element and a corresponding depth of penetration of the cutting element into the selected earth formation.

40. A method for balancing axial forces acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

simulating the drill bit drilling through an earth formation, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of an earth formation simulated as being drilled by the drill bit, an axial force acting on each of the cutting elements,

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements; repeating the incrementally rotating and recalculating for a selected number of simulated incremental rotations;

combining the axial force acting on the cutting elements on each one of the roller cones; and

adjusting at least one bit design parameter, and repeating the simulating until a difference between the combined axial force on each one of the roller cones is less than a difference between the combined axial force determined prior to adjusting the at least one initial design parameter.

41. The method as defined in claim 20 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

10. A method for balancing axial forces acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

simulating the rill bit drilling through an earth formation, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of earth formation simulated as being drilled by the drill bit, an axial force acting on each of the cutting elements,

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements; repeating the incrementally rotating and recalculating for a selected number of simulated incremental rotations;

combining the axial forces on the cutting elements on each one of the roller cones; and

adjusting at least one bit design parameter, and repeating the simulating until a difference between the combined axial force on each one of the roller cones is less than a difference between the combined axial force determined prior to adjusting the at least one initial design parameter.

11. The method as defined in claim 10 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

12. The method as defined in claim 11 wherein an incremental axial movement of the drill bit corresponding to the incrementally rotating is adjusted to cause the axial force on each of the cutting elements to total the axial force applied to the drill bit, the axial force acting on each of the cutting elements determined with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the

42. The method as defined in claim 20 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

43. The method as defined in claim 20 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

44. The method as defined in claim 15 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

45. The method as defined in claim 15 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

46. A method for optimizing a design of a roller cone drill bit, comprising:

simulating the bit drilling through a selected earth formation;

adjusting at least one design parameter of the bit, the at least one design parameter comprising a parameter selected from the group of a number of cutting elements on each one of a plurality of roller cones, cutting element type, and a number of rows of cutting elements on each one of the plurality of roller cones;

repeating the simulating the bit drilling; and

earth formation.

13. The method as defined in claim 12 wherein the predetermined relationship is determined by laboratory experiment comprising impressing a cutting element having known geometry onto a selected earth formation, while measuring force on the cutting element and a corresponding depth of penetration of the cutting element into the selected earth formation.

14. The method as defined in claim 10 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

15. The method as defined in claim 10 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

20. The method as defined in claim 16 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

21. The method as defined in claim 16 wherein the at least one bit design parameter comprise a location of cutting elements on at least one of the cones.

22. A method for optimizing a design of a roller cone drill bit, comprising:

simulating the bit drilling through a selected earth formation;

adjusting at least one design parameter of the bit, the at least one design parameter comprising a parameter selected from the group of a number of cutting elements on each one of a plurality of roller cones, cutting element type, and a number of rows of cutting elements on each one of the plurality of roller cones;

repeating the simulating the bit drilling; and

repeating the adjusting and
simulating until an optimized design is
determined.

47. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and
simulating until a rate of penetration of the
bit through the selected earth formation is
maximized.

48. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and
simulating until an axial force on the bit is
substantially balanced between the roller
cones.

49. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and
simulating until an optimized design is
determined.

23. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and
simulating until a rate of penetration of the
bit through the selected earth formation is
maximized.

24. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and
simulating until an axial force on the bit is
substantially balanced between the roller
cones.

25. A method for optimizing a design of a
roller cone drill bit, comprising:

simulating the bit drilling through a
selected earth formation;

adjusting at least one design
parameter of the bit;

repeating the simulating the bit
drilling; and

repeating the adjusting and simulating until a volume of formation cut by the bit is substantially balanced between the roller cones.

50. A method for optimizing a design of a roller cone drill bit, comprising:

simulating the bit drilling through a selected earth formation;

adjusting at least one design parameter of the bit;

repeating the simulating the bit drilling; and

repeating the adjusting and simulating until an optimized design is determined, wherein the simulating comprises:

selecting bit design parameters;

selecting drilling parameters;

selecting an earth formation to be represented as drilled;

calculating from the selected parameters and the formation, parameters for a crater formed when one of a plurality of cutting elements on the bit contacts the earth formation, the cutting elements having known geometry;

calculating a bottomhole geometry, wherein the crater is removed from a bottomhole surface;

incrementally rotating the bit; repeating the calculating of the crater parameters and the bottomhole geometry based on calculated roller cone rotation speed and geometrical location of the cutting elements with respect to rotation of the bit about its axis.

repeating the adjusting and simulating until a volume of formation cut by the bits is substantially balanced between the roller cones.

26. A method for optimizing a design of a roller cone drill bit, comprising:

simulating the bit drilling through a selected earth formation;

adjusting at least one design parameter of the bit;

repeating the simulating the bit drilling; and

repeating the adjusting and simulating until an optimized design is determined, wherein the simulating comprises:

selecting bit design parameters;

selecting drilling parameters;

selecting an earth formation to be represented as drilled;

calculating from the selected parameters and the formation, parameters for a crater formed when one of a plurality of cutting elements on the bit contacts the earth formation, the cutting elements having known geometry;

calculating a bottomhole geometry, wherein the crater is removed from a bottomhole surface;

incrementally rotating the bit; repeating the calculating of the crater parameters and the bottomhole geometry based on calculated roller cone rotation speed and geometrical location of the cutting elements with respect to rotation of the bit about its axis.

27. The method as defined in claim 26,

wherein the calculated crater parameters are derived from laboratory tests comprising a cutting element having selected geometry be impressed on an earth formation sample with a selected force, the tests generating at least a correspondence between penetration depth of said cutting element into the formation and the selected force.

There are no differences between the party Chen's claims and the party Singh's claims listed side-by-side above. Thus, it is clear that the parties are claiming the same patentable invention.

Moreover, Chen submits that the subject matter defined by Singh's dependent claims 3, 4, 8, 9, 12, 13, and 16-19 would have been obvious to a person having ordinary skill in the art in the 1998-2000 time frame from the subject matter defined by their respective independent claims. Therefore, they should also be designated as corresponding to the proposed count.

IV. SUPPORT FOR COPIED CLAIMS

The application of the terms of claims 34-50 to the specification of the parent application is shown below:

Application Claims

34. A method for determining a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

Support in the Specification

Page 17 Line 3: "It is not difficult to calculate the volumes removed by each row

....

Let V_1 , V_2 and V_3 be the volume removed by cone 1, 2 and 3, respectively. ..."

Page 11 Line 8: "Designer can evaluate the force balance and energy balance conditions of existing bit designs."

Page 16 Line 12: "As we stated in previous sections, there are many parameters which affect bit balance conditions. Among these parameters, the teeth crest length, their positions on cones (row distribution on

selecting bit design parameters,
comprising at least a geometry of a cutting
element on the drill bit;

selecting at least one characteristic of
an earth formation to be simulated as being
drilled by the drill bit;

cone) and the number of teeth play a
significant role. An increase in the size of
any one parameter must of necessity result
in the decrease or increase of one or more of
the others."

Page 16 Line 20: "The first step in the
optimization procedure is to choose the
design variables. Consider a cone of a steel
tooth bit as shown in Figure 3. The cone has
three rows. For the sake of simplicity, the
journal angle, the offset and the cone profile
will be fixed and will not be as design
variables. Therefore the only design
variables for a row are the crest length, L_c ,
the radial position of the center of the crest
length, R_c , and the tooth angles....
Therefore, the number of design variables is
4 times of the total number of rows on a
bit."

Page 17 Line 15: "For example, V_{32} is the
element in the volume matrix representing
the rock volume removed by the second row
of the third cone. The elements V_{ij} of this
matrix are all functions of the design
variables." Applicant submits that:
"Design variables" and "design parameters"
are synonymous.

Page 13 Line 13: "The force-cutting
relationship for this single element may be
described by:

$$F_{ze} = k_c * \sigma * S_c \quad (1)$$

$$F_{xe} = \mu_x * F_{ze} \quad (2)$$

$$F_{ye} = \mu_y * F_{ze} \quad (3)$$

Where F_{ze} is the normal force and F_{xe} , F_{ye} are
side forces, respectively, σ is the compressive
strength, S_c the cutting depth and k_c , μ_x and
 μ_y are coefficient associated with formation
properties."

Page 7 Line 15: "More recently, computer
programs have been developed which
predict and simulate the bottom hole
patterns developed by roller cone bits by
combining the complex movement of the
teeth with a model of formation failure.
(Ma, ... 1995)."

simulating drilling of the earth formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations; and

Page 13 Line 26: "There are many types of inserts used today for roller cone bit depending on the rock type drilled."

Page 20 line 1: "... the volume of formation removed by each tooth in each row, of each cutting structure (cone), is calculated. This calculation is based on input data of bit geometry, rock properties, and operational parameters."

Page 17 Line 20: "... the volume matrix calculated in a 2D manner must be scaled. The scale matrix, K_v , may be obtained as follows.

$$K_v(i,j) = V_{3d0}(i,j) / V_{2d0}(i,j) \quad (9)$$

where V_{3d0} is the volume matrix of the initial designed bit (before optimization). V_{3d0} is obtained from the rock bit computer program by simulate [simulating] the bit drilling procedure [for] at least 10 seconds."

Page 14 Line 21: "At any time t , the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained."

Page 27 line 8 (*Claim 10 as filed*): "(d) calculating the volume of formation displaced by a crater enlargement parameter function."

Page 14 Line 10: "(1) The bit kinematics is described by bit rotation speed, Ω =RPM (revolutions per minute), and the rate of penetration, ROP. Both RPM and ROP may be considered as constant or as [varying] function with time.

(2) The cone kinematics is described by cone rotational speed. Each cone may have its own speed. The initial value is calculated from the bit geometric parameters or just estimated from experiment. In the calculation the cone speed may be changed based on the torque acting on the cone. ...

(5) After the bit is fully drilled into

the rock, these forces are recorded at each time step. A period time usually at least 10 seconds is simulated."

Page 19 line 10: "Figure 6 shows the flowchart of the optimization procedure. The procedure begins by reading the bit geometry and other operational parameters. The forces on the teeth, cones, bearings, and bit are then calculated. Once the forces are known, they are compared, and if they are balanced, then the design is optimized. If the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance. This process is repeated until the desired force balance is achieved."

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones.

Page 21 Line 22: "(a) calculating the volume of formation cut by each tooth on each cutting structure; (b) calculating the volume of formation cut by each cutting structure per revolution of the drill bit;"

Page 17 Line 8: "... the objective is to let each cone remove the same amount of rock in one bit revolution. This is called volume balance or energy balance. ...

The volume matrix has the final form:

$$V_b(I,j) = K_v(I,j) * V(I,j) = f_v(L_c, R_c, \alpha, \beta) \quad (10)$$

Let V_1 , V_2 and V_3 be the volume removed by cone 1, 2 and 3, respectively. ..."

Page 14 Line 6: "The element forces are integrated into tooth forces, the tooth forces are integrated into cone forces, the cone forces are transferred into bearing forces and the bearing forces are integrated into bit forces."

Although the passage at page 14 refers to summation of forces, the volumes are

35. A method for balancing a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

selecting at least one characteristic of an earth formation to be simulated as being drilled by the drill bit;

simulating drilling of the drill bit through the earth formation, the simulating comprising calculating from the selected bit design parameters and the selected earth formation characteristic, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

simulating incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of simulated incremental rotations;

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones; and

adjusting at least one of the bit design parameters, and repeating the calculating the crater volume, incrementally rotating and combining the volume simulating until a difference between the combined volume cut by each of the cones is less than difference in the combined volume determined prior to the adjusting the at least one of the bit design parameters.

similarly summed to calculate the cone volumes V_1 , V_2 and V_3 .

Page 10 Line 17: "The roller cone bit is energy balanced such that each of the cutting structures drill substantially equal volumes of formation."

Passages at Page 16 Line 12, Page 16 Line 20 and Page 17 Line 15, as quoted above for Claim 34.

Passages at Page 13 Line 13, Page 7 Line 15, and Page 13 Line 26, as quoted above for Claim 34.

Passages at Page 17 Line 20, Page 14 Line 21, Page 20 Line 1, and Page 27 line 8, as quoted above for Claim 34.

Passage at Page 14 Line 10 and Page 19 line 10 as quoted above for Claim 34.

Passage at Page 21 line 21, Page 17 Line 8, and Page 14 line 6 as quoted above for Claim 34.

Page 17 Line 2: "... the objective is to let each cone remove the same amount of rock in one bit revolution. This is called volume balance or energy balance."

Page 18 Line 4: "Let V_1 , V_2 and V_3 be the volume removed by cone 1, 2 and 3, respectively. For the energy balance, the objective function takes the following form:

$$\text{Obj} = (V_1 - V_m)^2 + (V_2 - V_m)^2 + (V_3 - V_m)^2 \quad (11)$$

Where $V_m = (V_1 + V_2 + V_3)/3$

Page 15 Line 9: "A bit is perfectly balanced if:

$$\omega_1 = \omega_2 = \omega_3 = 33.333\% \text{ or } \omega_0 = 0.0\%$$

$$\eta_1 = \eta_2 = \eta_3 = 33.333\% \text{ or } \eta_0 = 0.0\%$$

$$\lambda_1 = \lambda_2 = \lambda_3 = 33.333\% \text{ or } \lambda_0 = 0.0\%$$

$$\xi = 0.0\%$$

In most cases if ω_0 , η_0 , λ_0 , ξ_0 are controlled with some limitations, the bit is balanced. The values of ω_0 , η_0 , λ_0 , ξ_0 depend on bit size and bit type."

Page 19 Line 15: "If the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance."

Page 21 Line 26: "(c) comparing the volume of formation cut by each of said cutting structures with the volume of formation cut by all others of said cutting structures of the bit; (d) adjusting at least one geometric parameter on the design of at least one cutting structure; and (e) repeating steps (a) through (d) until substantially the same volume of formation is cut by each of said cutting structures of said bit.

Page 10 Line 17: "The roller cone bit is energy balanced such that each of the cutting structures drill substantially equal volumes of formation."

The specification discloses both force balancing and volume balancing as possible objectives. The description of Figure 6 specifically refers to the force balancing objective, but volume balancing is also very specifically disclosed as another possible objective.

36. A method for determining an axial force acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

simulating drilling of an earth formation by the roller cone bit, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;

repeating the simulating the incrementally rotating and recalculating for a selected number of incremental rotations; and

combining the axial force acting on the cutting elements on each one of the roller cones to determine the axial force acting on each of the roller cones.

37. The method as defined in claim 16 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

Page 19 Line 11: "The procedure begins by reading the bit geometry and other operational parameters. The forces on the teeth, cones, bearings, and bit are then calculated."

Page 14 Line 19: "At the initial time, t_0 , the hole bottom is considered as a plane and is meshed into small grids. The tooth is also meshed into grids (single elements). At any time t , the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained."

Page 22 Line 3: "(a) calculating the axial force acting on each tooth on each cutting structure; (b) calculating the axial force acting on each cutting structure per revolution of the drill bit;...."

Page 14 Line 29: "(5) After the bit is fully drilled into the rock, these forces are recorded at each time step. A period [of] time [of] usually at least 10 seconds is simulated."

Page 14 Line 26: "The element forces are integrated into tooth forces, the tooth forces are integrated into cone forces, the cone forces are transferred into bearing forces and the bearing forces are integrated into bit forces."

Page 14 Line 26: "The element forces are integrated into tooth forces, the tooth forces are integrated into cone forces, the cone forces are transferred into bearing forces and

38. The method as defined in claim 17 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

39. The method as defined in claim 18 further wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

40. A method for balancing axial forces acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

the bearing forces are integrated into bit forces."

Page 8 Line 24: "The present application teaches that roller cone bit designs should have equal mechanical downforce on each of the cones. This is not trivial: without special design consideration, the weight on bit will NOT automatically be equalized among the cones."

Passage at Page 14 line 26: as quoted above.

Page 14 line 21: "At any time t , the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained."

Page 17 line 10: "Suppose the bit has a cutting depth Δ in one bit revolution. It is not difficult to calculate the volumes removed by each row and the volume matrix may have the form:

$$V = [V_{ij}], \quad i=1,2,3; j=1,2,3,4,\dots \quad (8)$$

where i represent the cone number and j the row number."

Page 13 lines 6: "The present invention uses a single element force-cutting relationship in order to develop the total force-cutting relationship of a cone and of an entire roller cone bit."

Page 8 Line 24: "The present application teaches that roller cone bit designs should have equal mechanical downforce on each of the cones. This is not trivial: without special design consideration, the weight on bit will NOT automatically be equalized

simulating the drill bit drilling through an earth formation, the simulating comprising calculating, from a geometry of cutting elements on each of the roller cones and at least one characteristic of an earth formation simulated as being drilled by the drill bit, an axial force acting on each of the cutting elements,

simulating incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements; repeating the incrementally rotating and recalculating for a selected number of simulated incremental rotations;

combining the axial force acting on the cutting elements on each one of the roller cones; and

adjusting at least one bit design parameter, and repeating the simulating until a difference between the combined axial force on each one of the roller cones is less than a difference between the combined axial force determined prior to adjusting the at least one initial design parameter.

among the cones."

Page 10 Line 15: "The roller cone bit is force balanced such that axial loading between the arms is substantially equal."

Page 19 lines 12: "The forces on the teeth, cones, bearings, and bit are then calculated."

Page 22 Line 3: "(a) calculating the axial force acting on each tooth on each cutting structure; (b) calculating the axial force acting on each cutting structure per revolution of the drill bit; (c) comparing the axial force acting on each of said cutting structures with the axial force on the other ones of said cutting structures of the bit"

Page 22 line 7: "(d) adjusting at least one geometric parameter on the design of at least one cutting structure; (e) repeating steps (a) through (d) until approximately the same axial force is acting on each cutting structure."

Page 19 Line 13: "Once the forces are known, they are compared, and if they are balanced, then the design is optimized. If the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance. This process is repeated until the desired force balance is achieved."

41. The method as defined in claim 20 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

42. The method as defined in claim 20 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

43. The method as defined in claim 20 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

44. The method as defined in claim 15 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

45. The method as defined in claim 15 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

46. A method for optimizing a design of a roller cone drill bit, comprising:

Page 15 Line 9: "...the balance condition of a roller cone bit may be evaluated using the following criteria:

$\text{Max}(\omega_1, \omega_2, \omega_3) - \text{Min}(\omega_1, \omega_2, \omega_3) \leq \omega_0$

... where ω_i ($i=1,2,3$) is defined by $\omega_i = \text{WOB}_i / \text{WOB} * 100 \%$, WOB_i is the weight on bit taken by cone i .

... A bit is perfectly balanced if:

$\omega_1 = \omega_2 = \omega_3 = 33.333 \%$ or $\omega_0 = 0.0 \%$

... In most cases if $\omega_0, \eta_0, \lambda_0, \xi_0$ are controlled with some limitations, the bit is balanced. The values of $\omega_0, \eta_0, \lambda_0, \xi_0$ depend on bit size and bit type."

Page 15 Line 16: " ω_i ($i=1,2,3$) is defined by $\omega_i = \text{WOB}_i / \text{WOB} * 100 \%$, WOB_i is the weight on bit taken by cone i

A bit is perfectly balanced if: $\omega_1 = \omega_2 = \omega_3 = 33.333 \%$ "

Page 16 Line 15. "Among these parameters, the teeth crest length, their positions on cones (row distribution on cone) and the number of teeth play a significant role."

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Page 16 Line 15. "Among these parameters, the teeth crest length, their positions on cones (row distribution on cone) and the number of teeth play a significant role."

Page 1 line 8: "The present invention relates to down-hole drilling, and especially to the optimization of drill bit parameters."

Page 9 Line 24: "The present application describes bit design procedures which provide optimization of downforce balancing as well as other parameters."